"Is this seat taken?" Towards a Novel Robotic Cane for Participation in the Social Dynamics of Seat Choice for Blind Individuals

University of Colorado Boulder

Shivendra Agrawal, Mart Etta West, Bradley Hayes

CAIRO Collaborative AI and Robotics Lab

Motivation

Limitations of common mobility aids :

- Service dogs can cost upwards of $50,000 to train and incur $1,200 on average in annual care costs.
- Cane cannot find empty seats in unknown public places.

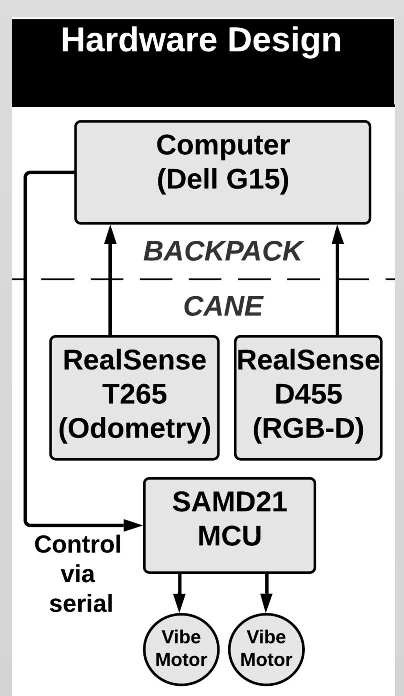
Motivation :

- Wang et al. showed that **finding seats in crowded public places is an important independent mobility task** for blind and visually impaired (BVI) people [1].
- Staats and Groot showed that **people prefer to seat themselves in a way that optimizes privacy and intimacy [2]**.

System Design

Two vibrational coin motors

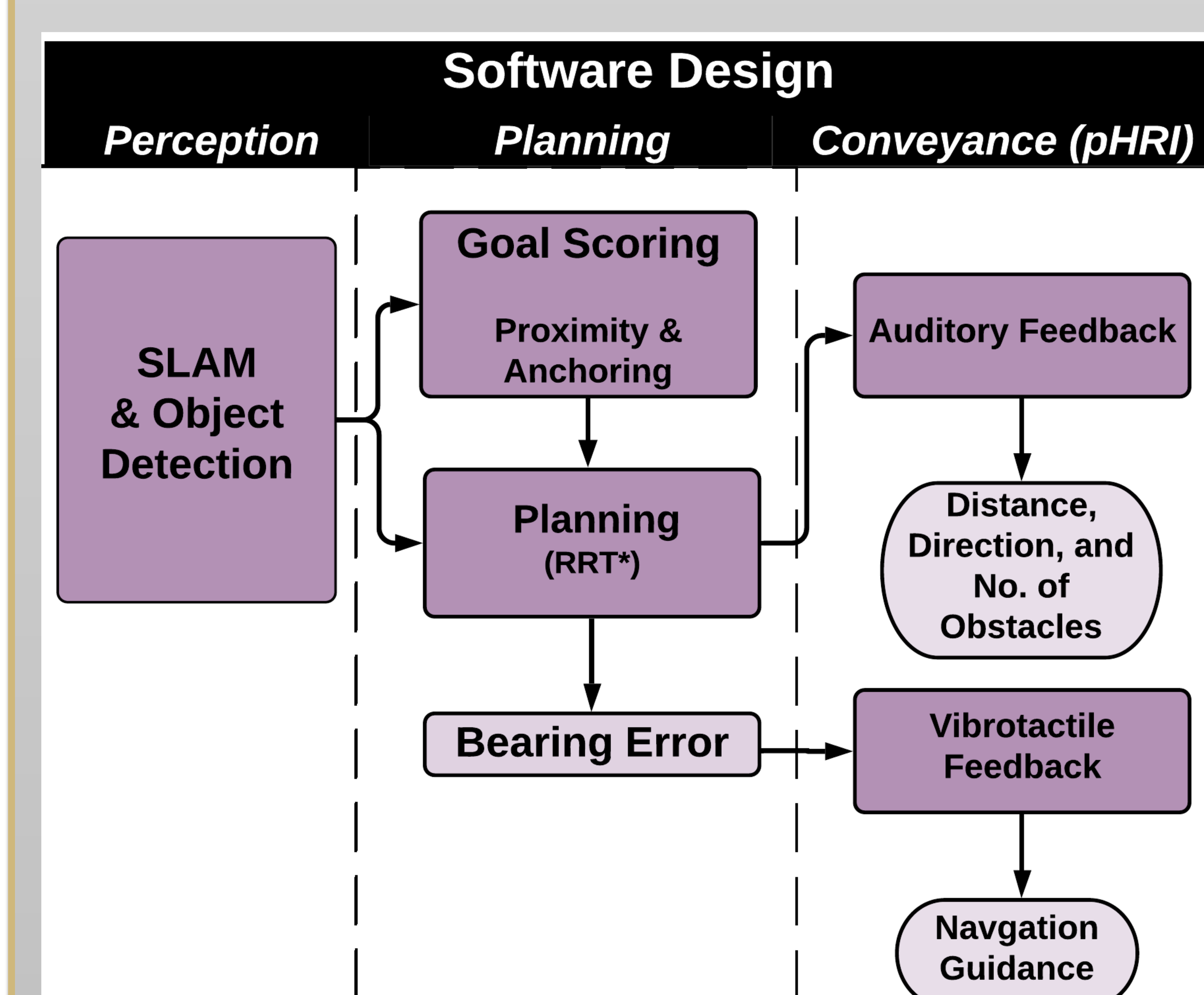
Depth Camera and IMU



Design Considerations :

- The cane should be able to function as regular cane and gather collision-based feedback from taps. .
- Vibration motors should be collocated & perceptible through one fingertip [3].

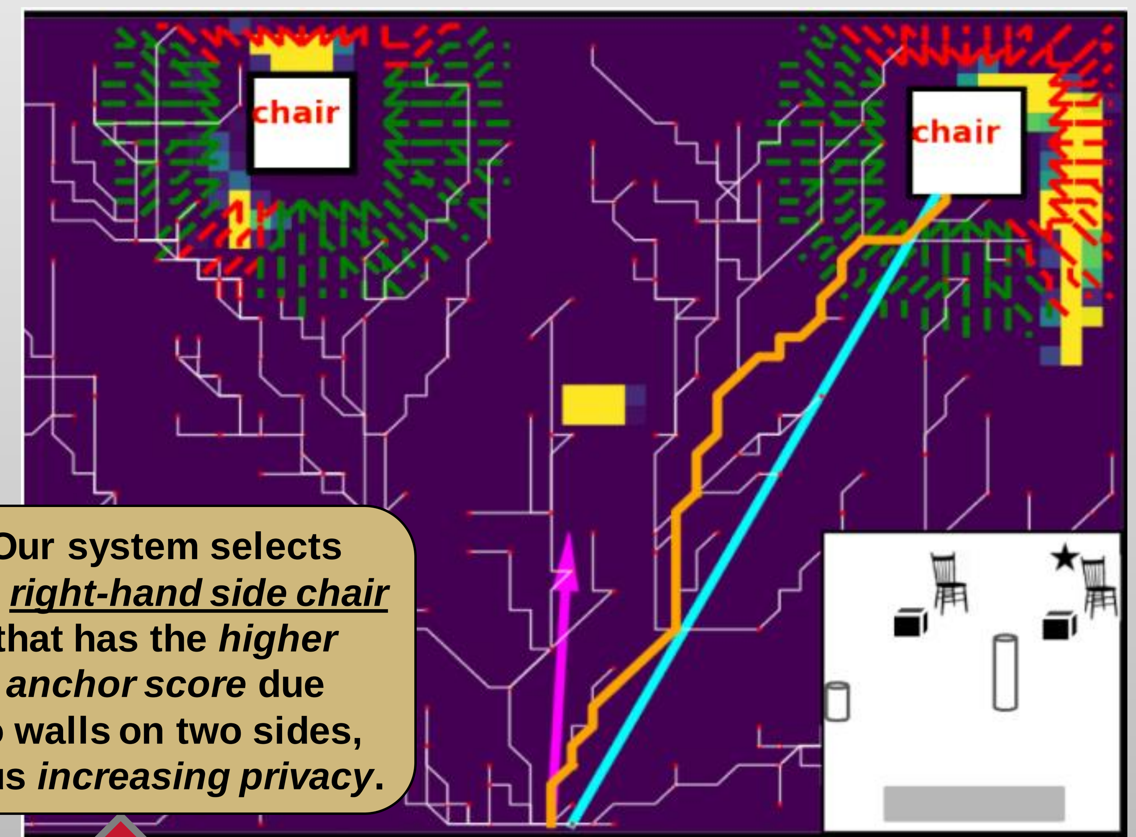
Software Design



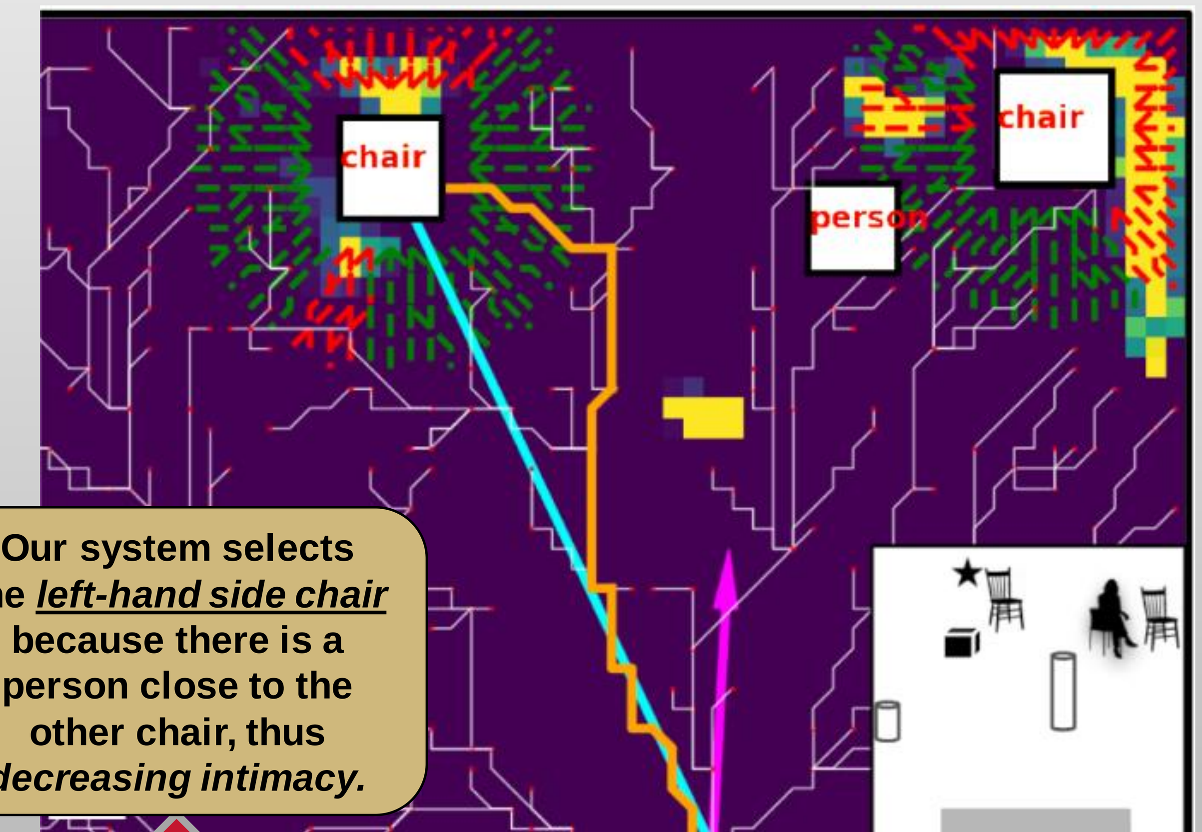
Perception :

- A SLAM algorithm creates a 2D occupancy grid using the RGB-D camera & the IMU while handling arbitrary tilts.
- We use detectron2 and Mask-RCNN for object detection.
- Next, we utilize an Extended Kalman Filter to model object positions as 2D Gaussians.

Goal Scoring and Planning on real-world data

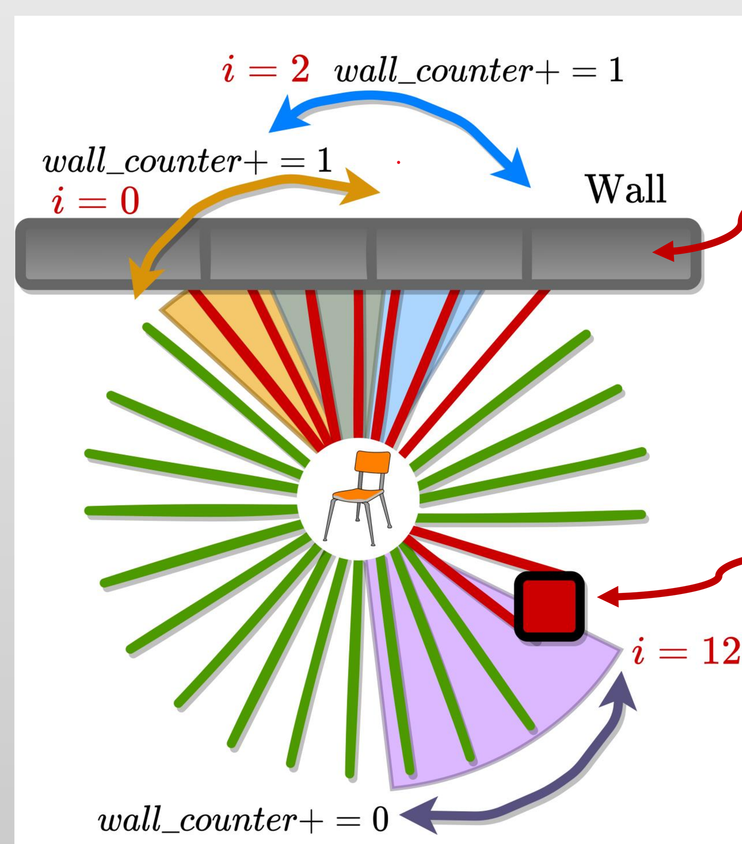


Our system selects the ***right-hand side chair*** that has the ***higher anchor score*** due to walls on two sides, thus ***increasing privacy.***



Our system selects the ***left-hand side chair*** because there is a person close to the other chair, thus ***decreasing intimacy.***

Anchor Score

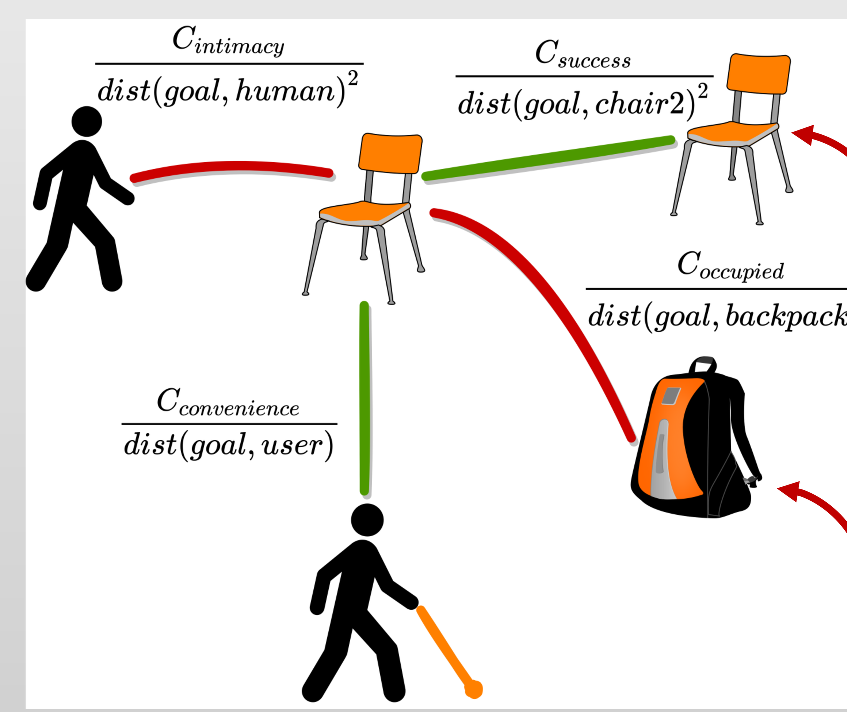


Contiguous objects like walls are given ***more votes*** and increase the anchor score of a chair.

Small objects are ***undercounted,*** thus contribute very little towards the anchor score of a chair.

- Anchor scores are calculated using a sliding window to track object-intersection density with radially cast rays.
- Here windows at i=0, i=2 get sufficient object-intersecting rays' density whereas window at i=12 does not, causing it to not contribute to the anchor score.

Proximity Score



Parameter	Role
$C_{intimacy} = -6$	Penalizes nearness to other humans
$C_{convenience} = 1$	Rewards nearness with the user
$C_{occupied} = -1$	Penalizes nearness to failure-correlated objects
$C_{success} = 1$	Rewards nearness to success-correlated objects

Objects correlated with ***success*** a increase the score

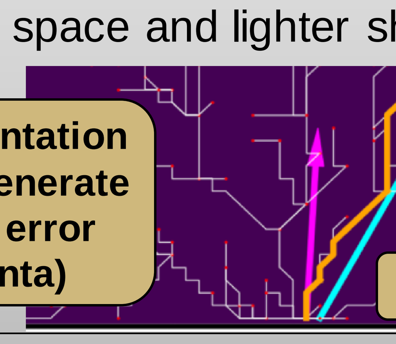
Objects correlated with signs of occupancy decrease the score

- A chair's proximity score is affected by its relative position with respect to other objects, humans and the user.
- We add the scores shown by the green lines and subtract the ones shown by the red.

Path planning and Plan Conveyance

Path Planning :

- We use RRT* to find a path towards the goal.
- The dark space on the the real-world data visualization show free space and lighter shows occupied space.



User Orientation used to generate bearing error (Magenta)

RRT* Path (Orange)

Optimized Path (Cyan)

Plan Conveyance :

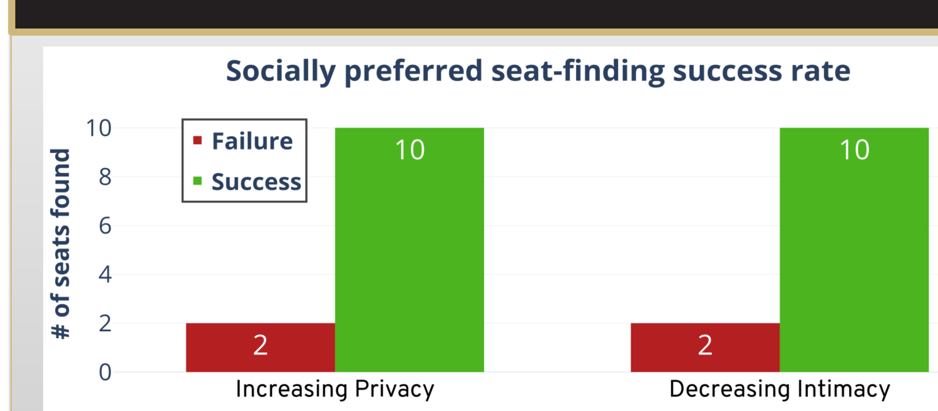
- ***Verbal goal overview:*** We generate a semantic description of the goal's relative location with the following template:

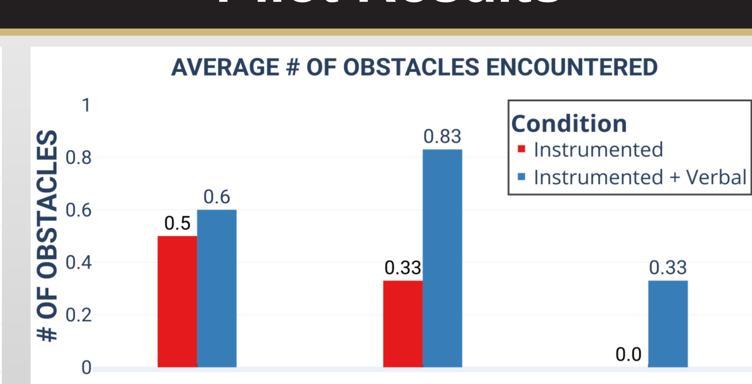
"{Goal Object} found about {} meters away in the {} o'clock direction"

- ***Vibrotactile guidance:*** Bearing error is encoded into two distinct haptic animation [4] patterns on each motor (left and right), creating five possible codes for conveyance:

hard-right, soft-right, straight/no animation, soft-left, and hard-left

Pilot Results





- **The users had 83.3% success rate at finding more socially-preferred seats.**
- **Even though the rooms had obstacles and walls, the users often were able to avoid collisions.**

Experiment: A total of six blindfolded users navigated through six scenarios done over three different room layouts to find a chair.

Moreover, the users reported **positive user experience** (Following are for verbal enabled).
- ***Confidence in navigation*** : **4.83 ± 0.41**
- ***Confidence in finding the goal*** : **4.5 ± 0.84**
- ***Verbal overview's helpfulness*** : **4.67 ± 0.82**

References: [1] H.-C. Wang, R. K. Katzschmann, S. Teng, B. Araki, L. Giarré, and D. Rus, "Enabling independent navigation for visually impaired people through a wearable vision-based feedback system," in 2017 IEEE International Conference on Robotics and Automation (ICRA), 2017, pp. 6533–6540.
[2] H. Staats and P. Groot, "Seat choice in a crowded café: Effects of eye contact, distance, and anchoring," Frontiers in Psychology, vol. 10, p. 331, 2019.
[3] R. W. Cholewiak, "The perception of tactile distance: Influences of body site, space, and time," Perception, vol. 28, no. 7, pp. 851–875, 1999, pMID: 10664778.
[4] Williams, Michele A., et al. "" just let the cane hit it" how the blind and sighted see navigation differently." Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility. 2014.